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Strengthening Student Understanding Through Interactive Classroom Methods in Computer Science and Engineering

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Abstract

This paper assesses the impact of various in-class instructional tools in post-secondary engineering curriculum. Various interactive methods were employed in university classrooms in Canada and the United States and analyzed to assess their effectiveness. These methods were evaluated to determine their efficacy in stimulating students, prompting critical thinking, and deepening overall understanding. The overall goal of each method is unique and the outcomes of implementing them in a classroom setting are presented in this paper.

Student engagement and attendance was seen to increase as a result of iClicker use and the associated participation points. Additionally, Google forms were used to capture student responses of in-class practice of Boolean Algebra. Students found the forms to be helpful in comparing their responses with other students' responses. The forms also helped the instructor gauge the class understanding by viewing the student response summary. This prompted the instructor to either explain the material in a different manner or move to another topic depending on the number of correct responses. The instructor could also identify the areas where students struggled the most. The third method, Immediate Feedback Assessment Technique, was used to solidify students' understanding of test concepts, provide immediate feedback on whether they approached the concept correctly, and provide an opportunity to improve their grades. Overall, it was found that the interactive activities discussed in this paper increased engagement, information retention, critical thinking skills and overall learning experience of the engineering students.

1. Introduction

Incorporating interactive teaching methods into post-secondary classrooms is not commonplace in North America, and there is uncertainty as to the efficacy of certain methods for engineering education. Traditionally, engineering education has not included interactive activities focussed on real world applications. Rather, teaching methods have been restricted to traditional formats including equations and step-by-step procedures which can restrict students' creativity, critical thinking, and information retention. A study by the National Academy of Engineering (2005) recommends learning environments that foster problem solving, student engagement and collaboration. Research has shown that using student-centered active learning strategies in the classroom leads to enhanced learning (Benson et al., 2010). According to Towner (2017), engineering education must be re-evaluated to increase "value added time" in the classroom. Therefore, it is important to incorporate teaching methods that provide more opportunities for student learning and development of critical skills.

Based on information provided in existing literature, three different in-class instructional methods were evaluated in college classrooms in Canada and the United States to determine their efficacy in providing students with a more valuable educational experience. These methods include the use of iClickers, Google forms and immediate feedback assessment techniques (IF-AT). Some of these methods emphasize collaborative learning, where students learn with and from each other in small groups. Collaborative learning has been shown to improve student performance, communication skills and enthusiasm for learning (Herkert, 1997). In the following sections, existing literature, instructor observations and student feedback will be analyzed to determine method efficacy and identify areas for improvement. Finally, recommendations are provided based on lessons learned.

2. Methods

2.1. iClickers

An iClicker is a student response system which allows students to answer questions without having to speak in class and which allows instructors to quickly gauge class understanding. Current literature identifies iClickers as a teaching tool to help keep students engaged in a large class (Barber & Njus, 2007) and to increase student engagement and achievement (Gilson, 2010). Furthermore, iClickers have been shown to improve class attendance if the students are aware that their participation is being recorded and evaluated. In this study, iClickers were used to provide students with an opportunity to discuss engineering application questions amongst themselves with instructor support, when required.

Student engagement and responses were monitored for two math courses and two mechanics courses within the Civil Engineering faculty of the University of X. The monitored courses were Advanced Math for Civil Engineers, a third-year math course, Advanced Calculus, a second-year math course, Mechanics 2 a first-year mechanics course, and Solid Mechanics 1, a second-year mechanics course. The second-year mechanics course was taught for three years without the use of iClickers, which served as a control group of the study.

In these cases, the professor taught a concept and often completed an example question on the board to provide the students with a better idea of how the concept could be applied. Following the lesson, the professor displayed a multi-step question on the projector and gave the students time to solve the problem and choose the final answer from the set provided using their iClicker. During this time, students could co-operate and discuss their strategies with their peers while the instructors moved through the room to answer questions. Once the class had responded, the answer was revealed, and the problem was solved as a group on the board. This exercise was intended to provide the students with an opportunity for peer learning. It has been demonstrated that engaging students in small group, peer-led discussion can improve overall student problem solving skills (Repice, et al., 2016). To further guide the students in their discussion, the instructor was made available to answer questions raised by the student groups. It has been observed that providing instructor feedback is essential to guide peer teaching, since it allows students to feel comfortable in expressing their ideas, as they can ask their instructor for guidance (Lynch, McNamara, & Seery, 2012).

Based on the existing literature, it was anticipated that using iClickers in this way would provide students with stronger problem solving and communication skills. This was noticed in the performance change that the students showed in the second-year mechanics course. While the participation in the course before the use of clickers was limited to the few students who were already engaged, the use of clickers increased the participation and the instructor noticed the increase in the number of students who would ask question. Assessment for this method was qualitative and based on the course evaluations.

2.2. Google Forms

Google forms, part of the Google application suite is a free electronic online tool that can be used to create quizzes, surveys and polls. The tool also offers the instructor the ability to track the emails of the participating students and their responses. These responses can be seen as charts, which provides information on how well the class understands the materials being taught.

Computer organization and architecture is a highly mathematical based course that also requires a good knowledge of physics. Boolean Algebra is one of the concepts that challenges students in computer architecture. Boolean Algebra helps students learn to design the logic and circuits of the computer. Boolean algebra optimization is also used to optimize the architecture and design of circuits in a computer. Engagement in mathematical subjects has reviewed by scholars and various proposals have been proposed to encourage student engagement in mathematics. One popular approach is the recommendation to view mathematics as a dynamic and exploratory subject rather than a static subject. This view was a major reform in fostering student engagement to the level of doers and thinkers rather than observers (Henningsen and Stein, 1997). This means utilizing tools that would engage in a more dynamic and regenerative manner, providing opportunities to explore the concepts to better understand the reasoning processes (Burton, 1984, Romberg, 1992). Google Forms were used as a tool to engage students in the class in University Y. The instructor created problems for students to solve in Google forms. The students were given access to these Google forms before the start of the class. The Google forms offered the students an opportunity to see each other's work and compare their answers with their peers' work. This gave them an idea of how they were doing in the class in comparison to their peers. Figure 1 below shows that students did not understand the material well and hence there was a wide range of answers given. The correct answer was AB+AC+AC.

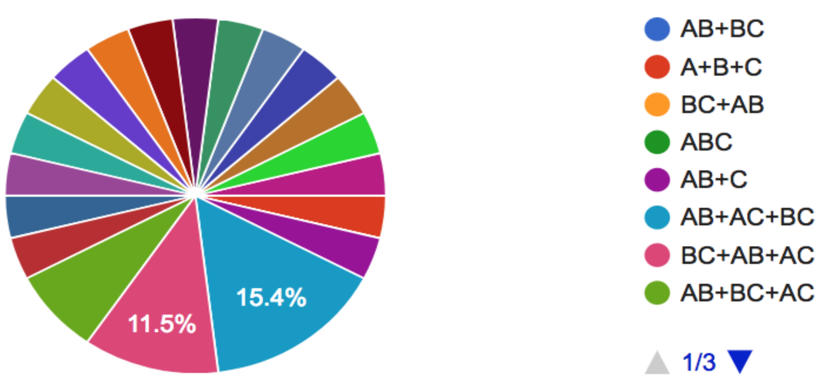

Figure 1. Students responses showing a wide range of responses and few correct answers.

Figure 2 below shows better understanding compared to figure 1. However, a significant number of responses are incorrect. Here the correct answer was Ab+cd. Figure 3 shows major improvements in the understanding when compared to figure 2. Here the answer is A.

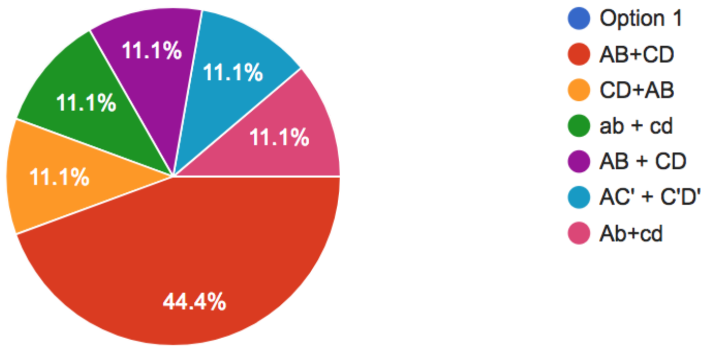

Figure 2. Student responses showing some improvement in accuracy.

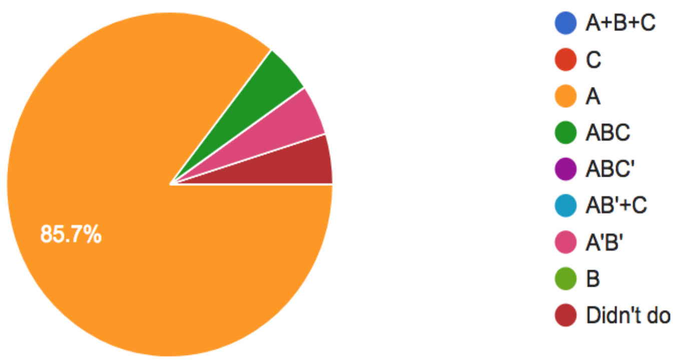

Figure 3. Student responses showing vast improvement in accuracy.

As seen in Figure 4 and 5 below accuracy of student responses is significantly improved with a 100% accuracy in figure 5. The correct answer here is A+C for Figure 4 and B+C for Figure 5.

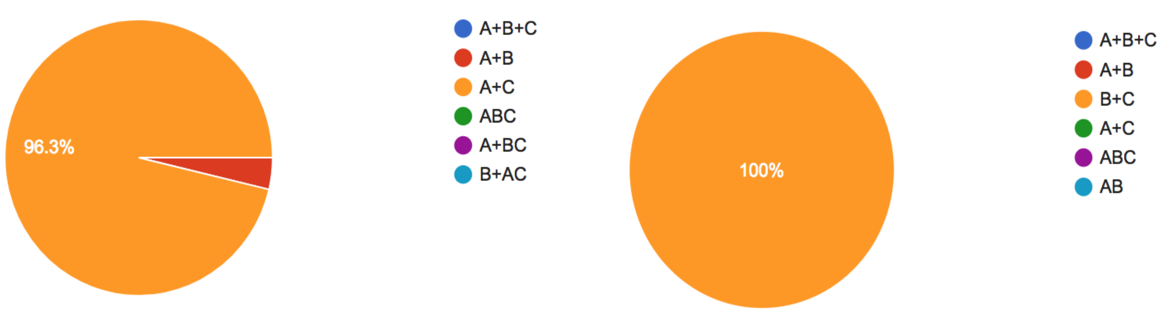

Figure 4 and 5. Student responses showing 96% and 100% accuracy.

2.3. Immediate Feedback Assessment Techniques

In this study, students were given IF-AT assessments directly after completing a unit quiz. The IF-AT, is a transformed multiple-choice testing technique that provides students with immediate feedback on their responses. The IF-AT has been used in the past to show that correcting student's misconceptions immediately after an assessment can improve knowledge retention, and thus test scores. Epstein et. al (2001) has expressed that "examinations should assess students' knowledge, correct false impressions, and produce new knowledge". In a 2001 study, final exam results were compared for students who were tested using the IF-AT format for their unit tests and for those who were tested using a traditional Scantron for their unit tests. All students completed the final exam using a Scantron format. It was found that students who were evaluated using IF-ATs for their unit tests correctly answered more questions on the final exam that were repeated from previous unit tests than the students who completed Scantrons for their unit tests (Epstein et al., 2001). This indicates that information retention for the students testing using the IF-ATs was higher than those who were not tested in this way.

With respect to this study, the IF-AT quizzes were used to further solidify students' understanding of test concepts, provide immediate feedback on whether they approached the concept correctly, and provide an opportunity for participation marks. The IF-AT quizzes were integrated into first and second-year engineering mechanics courses, taught to civil, environmental and geological engineering students. During the course, the students were tested on their understanding using three problem-based quizzes. After the allotted quiz time, the students were divided into groups of four and given a group quiz that had all the same problems as the original quiz; however, the numbers were changed, along with an IF-AT scratch cards that shows where the correct answers are. Students were encouraged to go over each question as a group, discuss how each person approached the question and determine which approach was correct. Once an approach was decided on, the students would solve the question together and scratch the IF-AT card to determine if their answer was correct. Full credit was awarded if the first attempt was correct, partial credit were awarded for each attempt following, and no credit were given if none of the answers chosen were correct (i.e. if all the options were scratched out). This approach aimed to achieve peer learning through group discussion and solidification of concept understanding through repetition and immediate feedback.

3. Results and Discussion

3.1. iClickers

Feedback on iClickers was received via anonymous student evaluations from two civil engineering classes; Advanced Calculus and Advanced Math for Civil Engineers. The evaluations consisted of a ranking portion as well as a short answer section. In the short answer portion, the students were asked to provide answers to the following prompts: "Your professor would like to know if there is something you believe he or she has done especially well in his teaching of this course" and "Your professor would also like to know what specific things you believe might be done to improve his or her teaching of this course". Only the short answer portion of the evaluations that pertained to iClickers are used for this paper. If the students answered the first question, it was considered a "positive" comment, and if the second question was answered, it was considered a "negative" comment.

The Advanced Calculus class consisted of 46 students, and the instructor used at least one iClicker question in each lecture. Additionally, in a few cases the instructor would take over tutorial sessions and give iClickers during that time as well. For this class, 23 positive comments and 8 negative comments were received, for a total of 31 responses. Feedback from the positive comments showed that students liked that iClickers were used only for participation marks, that iClickers helped to confirm their understanding of course concepts, and that it helped students to keep up to date with what was being taught in class. Feedback from the negative comments indicated that while iClicker questions are helpful, they took up too much time during lectures to complete.

The advanced math for civil engineering class consisted of 111 students, and iClicker questions were limited to 3 questions per week, often in the same lecture. iClicker questions were mainly conceptual in nature, rather than computational, and they were related to the concept being covered in class that week. For this class, 40 positive comments, and 23 negative comments were received. The positive comments expressed that iClickers improved class engagement, reinforced concepts learned in class, identified weak points in students' understanding, encouraged students to work together, and helped to prepare students for quizzes and exams. Some students commented that it was helpful having an instructor "fill in voids" while they were solving the iClicker questions. The negative comments expressed that iClickers take up too much time in class, solutions should be posted online to provide more practice prior to quizzes and exams, and that graded assignments would be more beneficial. Additionally, some students expressed that more iClicker questions should be provided in class, and that more time should be provided to answer iClicker questions.

Based on the positive feedback, the instructor added the use of iClicker questions to the rest of the courses that were originally taught without iClickers, such as the second-year mechanics course. The instructor so an increased number of participating students as well as more discussions were triggered in class as a result of the use of iClickers in comparison to the years when the iClickers were not used.

3.2. Google Forms

It is often difficult to be aware of the student understanding of the materials being covered in class. One mechanism is to use Google forms where the faculty can ask the students a question in Google forms and from their replies can gauge if the class answered that question correctly or not. If all or majority of the students answered the question correctly (Figure 5) this meant they understood the material and if few answered correctly (Figure 1) then this meant that they did not understand the materials. Google forms were used in CS 2521 Computer Organization and Architecture with 55 students. The instructor started the class by first reviewing the material covered in the previous class and then introduced new material to the class. To help the students understand the new technical material introduced to the class, the instructor created problems for groups of three students to solve in class. These problems were offered to the students for the duration of the entire semester. In the first half of the semester the students were given these problems by displaying the questions in PowerPoint slides and in the second half of the semester these questions were offered to the students in Google forms.

At the end of the semester the students completed a survey in Google forms. 46 out of 55 students completed the survey and the results were mixed. When the students were asked the question- “Did you like using google forms in class for in-class exercises” 30.4% liked using the forms while 45.6% did not like them and 23.8% were neutral. Although they did not seem to like the forms they liked seeing their peers’ responses. When asked “You could see other student responses when using google forms. Did you like that”, 50% of the students liked it while 43.5% were neutral and only 6.5% did not like this ability. When asked if the students liked the option of being able to see their peer responses to see if they were understanding the material, 63.1% of the students liked while 6.5% did not like it and the rest 30.4 were neutral. Asking the students if they liked the ability to go back to review the materials in Google forms, 58.7% liked it while 17.4% did not like it and 23.9% were neutral. When asked if the instructor should continue to use the Google forms for future classes only 17.4% of the students did not agree.

To get a qualitative perspective on the use of Google forms the students were also asked to leave comments. Majority of the comments implied they appreciated the use of Google forms and liked the fact that the instructor could use the Google forms to gauge the understanding of the materials by the class. Some comments such as “Really helps show where each student is on the subject”, “I think this was a very useful way to see what the class understands”, “I think that's perfect”, “I think that it was very helpful as then the lectures could be changed to keep everyone up on information.”

3.3. Immediate Feedback Assessment Techniques

The Immediate Feedback Assessment Techniques appeared to be well received, as students were actively participating with their classmates. Students in general responded positively to the IF-AT quizzes acknowledging that they helped with understanding the concept error they got in the individual quizzes and there were no surprises when they received their individual quizzes back. However, students felt tired doing the group IF-AT quiz right after the individual quiz especially when these were offered late in the afternoon.

The IF-AT quizzes were not popular with some students, as they typically enjoy the so called “bubble” of ignorance after a challenging quiz is written. During this “bubble”, the outcome of the quiz is unknown, and the student does not have to deal with the reality of a poor mark. However, with the IF-AT quizzes, students were often able to determine whether they completed a question correctly on their quiz based on the outcome of the IF-AT. While the IF-ATs may not have been popular, they are not believed to be ineffective. In university, quizzes and tests are not “taken up” or reviewed by instructors in class like they are in grade schools. Many students do not review their tests until they are using it to study for the final exam, at which point getting instructor feedback may be difficult due to a high quantity of students seeking their attention during this time. The benefits of reviewing a test with an instructor right away is that a student can correct their understanding of a concept and can apply this understanding to future concepts. This is especially helpful in the mechanics course, as it serves as a building block for many courses that students will take in the future. It is expected that learning their mistakes in a timely fashion will ultimately help their learning and overall course performance.

Most students received a very high grade on their IF-AT quizzes. This is expected because of the peer to peer learning that was able to take place during the quiz discussion time. Often, there would be one or two students in each group that was confident in a particular answer and would help the remaining group members to understand how to solve the problem.

4. Recommendations

4.1. iClickers

From the feedback received from the course evaluations, it was gleaned that iClickers are a great tool for use in the engineering classroom; however, it was noted that they take up too much time in class, and that questions and solutions should be posted prior to quizzes and exams for extra practice. To reduce the amount of time taken in class, it is recommended to ask concept questions, or to break computation questions down into a single step format, rather than a large question with multiple steps required to solve for a final answer. Additionally, the instructor found that allowing one additional minute to answer once 50% of the class had submitted their answer was good practice for iClicker questions. This was seen to be a satisfying compromise between the students who believed that iClickers took too long, and the students who felt rushed.

4.2. Google Forms

From the student responses to the survey questions it appears that there are certain features of the Google Forms that the students liked while there were others that they did not like. The Google forms were used in this class for the first time and there were occasions when the forms did not work as predicted due to some setting issues. The recommendations to use Google forms would be to set up the forms so that the students can enter appropriate style of answers such as multiple choice/short answer/paragraph or more. Also, the settings should reflect the ability of the student to edit their answers and view the responses. If the correct format of the answer is not chosen, then the Google form will show not work as seen in Figure 6 below. Here the question should have been set up as a multiple choice with specific options instead it was set up as short answer question. Here you can see that some of the responses although correct were not considered correct due to the misalignment of the spaces.

4.3. Immediate Feedback Assessment Techniques

Based on the results from using the IF-AT quizzes in the mechanics class, it is not fully clear whether they were successful in increasing information retention in the students; however, since they were presented in a group setting, it is expected to improve peer to peer learning skills. Instructors received few questions related to unit quiz content or grades after the quizzes were administered. This is likely due to the peer-to-peer learning induced from the group quiz. Often, students would be able to determine the correct approach from each other. If they were unable to come up with a solution on their own, or had questions about either of the quizzes, instructors were moving about the room to answer any questions they had.

For future use, it is recommended to use a control group to determine if the IF-AT has an impact on information retention relative to the engineering curriculum. It is also recommended to continue use in the same way as outlined in this paper in order to provide immediate feedback to students and increase their ability to teach and learn from one another.

Figure 6. Inappropriate question style for Google form

5. Conclusions

The results of the study revealed that deviating from traditional teaching methods in engineering education is beneficial for improving overall student understanding and student satisfaction with their courses.

It was found that the majority of students enjoyed iClickers as a learning tool. Based on anonymous class evaluations, it was determined that students would prefer if the iClicker questions were asked in tutorials, as they took up a large portion of class time. Additionally, to reduce the amount of time taken for each iClicker question, the instructor allowed one minute for students to submit their answers once half of the class had answered the question. While there are no evaluations available to assess this method, it is believed to be a good practice for iClicker questions based on discussions with students.

The use of group IF-AT quizzes immediately after a unit quiz was seen to have a positive effect on developing peer-to-peer learning skills in engineering education. The students were put into groups of four to five and allowed to finish the IF-AT quiz, which mimicked the unit quiz they had just taken, together. As this was the first time the IF-AT quizzes were used in this way, it is not possible to discern whether this method influenced overall student grades. However, instructors noticed that they received few questions about quiz content when the IF-AT quizzes were being implemented. This is anticipated to be because many students were able to find the answers to their questions from their peers during the IF-AT quiz period.

Google forms if set up correctly can play the role of a tool to gauge the state of the understanding of the material by the class. Although the students did not like some of the features in Google forms they mostly appreciated the ability of the instructor to know if the students are understanding the materials or not.

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